NASA-CR-193353

Final Report for NASA Grant NAGW-1593

"Auroral Ion Heating and Wave Turbulence in a Multi-Ion Plasma"

A. Summary of Completed Project

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Ion-Ion Interaction Studies

In the auroral zone, quasi-static parallel electric fields produce beams of ionospheric ions (e.g. H^+, He^+, and O^+), which flow outward into the magnetosphere, providing a significant source of ions for the ring current and plasma sheet. Because the velocities to which these beams are accelerated is dependent on the mass of the ions, differential flows between the various ion species can develop which are unstable to an ion-ion streaming instability [Dusenbery and Martin, 1987; Dusenbery, et al., 1988].

Particle simulations and observations from DE 1 were used to investigate the heating of the ion beams produced by this instability [Winglee, et al., 1989]. It was shown that there was net transfer of energy from the light ions to the heavy ions, with the heavy ions reaching maximum velocities near the beam velocity of the light ions. Bulk heating of the heavy ions occurred when their relative density was low, while high-energy tails were produced when their relative density was high. The heating was primarily parallel to the magnetic field if the difference in the heavy and light ion beam velocities was subsonic, while both perpendicular and parallel heating could occur if it was supersonic. In the latter case, very strong heating of an intermediate ion species such as He^+ could also occur.

Comparison with observations showed features consistent with heating via the ion-ion instability, including perpendicular heating in the supersonic regime and parallel heating in the subsonic regime, and a change in the heating between these regimes as the ratio of the H^+ beam speed to the local sound speed was observed to decrease. This heating was, however, not always observed in association with enhanced wave emissions. This lack of waves was attributed to reabsorption of the waves as the ions became heated.

A Mesoscale Model For Auroral Particle Acceleration

We have been developing a model the auroral current system during active times. The model is important in two areas. First, it provides some insight into the coupling between the ionosphere and magnetosphere during substorms by prescribing the conditions in the magnetotail needed to establish the auroral current system and the response of the ionosphere to these currents. Second, it provides a detailed analysis of many of the important processes responsible for some of the unique features associated with particle acceleration in the auroral zone. Initial results will be have

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been submitted for publication in the *Proc. of the Chapman Conference on Substorms* edited by J. R. Kan.

The model utilizes two-dimensional (three velocity) particle simulations with a multi-ion component plasma, a collisional ionosphere and convergent magnetic field lines. The auroral current system is driven by a cross-field current in the magnetotail that can develop due to the differential motion of the electrons and ions through the magnetotail current sheet. As a result of this differential flow, there is charge-separation of the magnetotail ions and electrons which can be shorted out by field-align flows into and out of the ionosphere.

As these field-aligned flows develop, the quasi-static fields, mirror forces and wave-particle interactions drive the particle acceleration and heating. For the electrons, distinct beam features at high altitudes are generated in association with intense Langmuir and electron acoustic waves. At lower altitudes, the accelerated electrons appear more as a a high energy tail in the distribution and the electron acoustic waves are no longer present. The scattering produced by these waves enhances the influence of the mirror force producing a moderate upflowing component in the beam region which leads to the appearance of loss-cone and trapped distributions at high altitudes. Intense upper hybrid waves are generated by these features but they are most intense at low altitudes where mirror force also leads to a local temperature anisotropy. These waves can propagate across the field lines to produce electron conics in the return current regions.

The ion dynamics is just as intricate. They initially experience rapid perpendicular heating due to the relatively short scale lengths across the field lines compared to the parallel scale lengths. These energetic ions can propagate across the field lines to produce conics in both the beam and return current regions.

On longer time scales, upflowing ion beams are generated in the primary current region. The parallel energy of the light ions tends to exceed that of the heavy ionospheric ions during the initial stage of beam formation, primarily due to their shorter transit time through the potential drop. However, ion beams eventually becomes unstable to an ion-ion streaming instability which transfers energy from the light ions to the heavy ions [Dusenbery et al., 1988]. In the present work, the heavy ions have an average parallel energy about 20% larger than the light ions. This result is similar to the observations of Collin et al. [1987].

At the same time, the mirror force is acting on the perpendicularly heated ions. This is particularly important for ions in the return current regions where the mirror force produces an upward push against the electric field which drives the return current. Because of the preferential perpendicular heating of the ions, the mirror force dominates and upflowing ion conics can be present in the same region as upflowing return-current electrons. Ion cyclotron waves are seen in association with the beams and cyclotron absorption is seen in association with the conics, similar to the observations of Gorney et al. [1981].

B. References

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C. Conferences

"A Mesoscale Model for Auroral Particle Acceleration and Current System", G. A. Dulk, R. M. Winglee and P. B. Dusenbery, Western Pacific Geophysics Meeting, Kanazawa, Japan, August 21--25, 1990.

"Auroral Particle Acceleration: The Role of Quasi-Static Potentials and Double Layers", G. A. Dulk, R. M. Winglee, and P. B. Dusenbery, American Geophysical Union, Fall Meeting, San Francisco, December 3--7, 1990.

D. Relevant Publications

Dusenbery, P. B. and R. F. Martin, Jr., Generation of broadband turbulence by accelerated auroral ions; 1 Parallel propagation, *J. Geophys. Res.*, *92*, 3261, 1987.

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